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Decoration and Industrial Lighting*

By J. H. NELSON, Ph.D., A.Inst.P.*(Fellow)*

Synopsis

The purpose of industrial lighting and decoration is to provide conditions in which an operator can see to work and has the will to work. The fundamental researches on vision directly indicating the type of conditions desirable for good seeing are described and summarised in the form of a set of ideal seeing conditions. Not the least important of these conditions is the provision of agreeable surroundings by the choice of suitable decoration and lighting. Recent researches in colour harmony are described and, although, so far, experiments have been confined to a very restricted set of conditions, this work is used to draw up a series of practical recommendations on industrial decoration.

Since the type of decoration scheme suggested is quite different from that found in the majority of factories, details are given of two schemes which have been found successful. These schemes are illustrated by photographs and the practical experience gained since their installation over three years ago is described.

Introduction

Scientifically, industrial lighting is probably the most advanced of all the branches of illuminating engineering, but as far as the art of lighting is concerned it is the Cinderella among the lighting fields.

The causes of this state of affairs lie deep rooted in industrial life. In general there is no clearly defined factory lighting policy. The lighting installation was in the past definitely not part of the structure of a building, nor yet was it part of the workshop equipment. In this no man's land, the industrial lighting engineer has developed a masterly technique, but it is only if he is called in when a building is being designed that good "brightness engineering" can result. Again, many machine tools are so complicated that local lighting is essential and should be designed as an integral part of the mechanism.

The desirability of co-operation with the architect and decorator on the one hand and with the machine tool designer on the other has long been evident to the lighting engineer, but it is only recently that the fruits of such co-operation have been sufficiently widespread to influence the general trend of ideas in illuminating engineering. It is the purpose of this paper to discuss the roles of lighting and decoration in producing not only adequate illumination for the job, but also in contributing to the general sense of well-being which is induced by pleasing surroundings. Discussion of the scientific background to such a complex subject must not be taken to imply that any simple set of rules can be deduced which will do away with the necessity for the creative ability of the artist. Such is not the function of science in any circumstances. On the other hand a scientific analysis of the conditions necessary for comfortable seeing must be carried out if lighting is to be both a true science and an art. In fact, it is the artists who have, down the ages, amassed a wealth of knowledge concerning light and shade, and the rules of colour harmony together with the psychological effects of colour. However, much of this knowledge exists only as isolated notes by great artists and rarely is there any attempt to

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co-ordinate one observation with another. Such co-ordination is the function of a scientific examination and, although this can yield no new creation, the very act of relating a number of hitherto disconnected facts must enhance their value and aid their appreciation.

Ideal Seeing Conditions

Probably the most fundamental work on the requirements of the eyes for seeing is due to Lythgoe(1) and, although his curves have often been quoted, their lesson is so important that those dealing with the effect of an illuminated surround are reproduced. The results shown in Fig. 1 are the outcome of a series of experiments to determine the relation between the visual acuity and the brightness of the test object under these distinctly different conditions of the surround field, namely:—

(a) With the test object on a dark background.
(b) With the background raised to a constant brightness.
(c) With the background brightness equal to that of the test object.

It is quite evident that the visual acuity is highest when the test object and background brightness are the same, and it is also clear that, even at a brightness of 100 equivalent foot candles, the visual acuity is still rising with increased illumination. These results have been confirmed by Weston and by Luckiesh.

These results are obviously of paramount importance in determining our approach to the problems of illuminating engineering. They bring out clearly the fundamental difference between the reactions of the human eye and those of any physical apparatus.

The work of Lythgoe was concerned only with the conditions of an object on the border of visibility and the measurements were actually taken at the point when a test object either became just visible or just invisible. In practical problems the visibility must be very much higher than this. In fact illuminating engineering is concerned with making things easy to see and

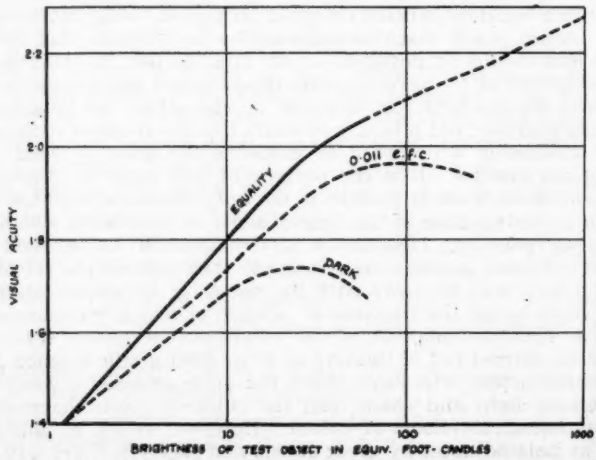


Fig. 1. Showing the relation between visual acuity and the test object brightness, (a) with a dark surround, (b) with a surround field brightness 0.011 e.f.c., (c) with surround field brightness equal to the test object brightness. (After Lythgoe.)

ensuring that the seeing task is well within the capacity of the worker. From the point of view of measurement this requirement makes it necessary to use an indirect approach to the problem since, so far, there is no means of measuring the degree of a sensation. It is possible to determine the level of illumination at which an object can just be seen. It is also possible to estimate the highest brightness of the object that can be tolerated. Between these two levels, however, there exists no criterion which can be fixed sufficiently definitely for measurement. Faced with the real practical problems of laying down definite recommendations for industry, Weston (2), in England, and Luckiesh (3), in America, have devised methods of assessing the lighting requirements for different tasks.

Weston's method, upon which is based the I.E.S. Code, is the result of a number of very thorough investigations on practical industrial jobs, combined with a critical method of analysis of the visual test. Briefly, Weston attempts to assess the best possible performance that can be achieved and then to provide such lighting that a 90 per cent. performance can be attained in practice. To aim at 100 per cent. would clearly be quite uneconomic, as the relation between the illumination and the response it produces is approximately logarithmic so that, whilst 90 per cent. or 95 per cent. is practical, 100 per cent. would in some cases lead to quite unreasonable levels of illumination. It is important to note that the approach to the problem of recommending a suitable illumination is through the brightness of the object. The illumination is, in fact, a derived quantity and if a fundamental approach is to be made it must be in terms of the brightness of the visual field.

The technique used by Luckiesh for estimating the case of seeing has been the subject of very considerable controversy. In order to assess the degree of strain experienced by a subject performing a visual task, Luckiesh sought to find some involuntary nervous sign not necessarily directly associated with vision. Exhaustive experiments with a number of subjects led him to the conclusion that a change in the involuntary blinking rate could be taken as a direct indication of the degree of strain imposed by a severe visual task. Although other workers have been unable to repeat his experiments, it must be admitted that many of the practical recommendations made as the result of his researches are quite consistent with those arrived at by other methods of investigation.

The recommendations which result from the experimental work described concern:—

(a) The illumination and resulting brightness of the visual task;
(b) The surroundings of the task in the visual field.

Whilst it is evident that central field brightnesses of the order of 1,000 equivalent foot candles will result in the best conditions for seeing, the effect of departures from such a high level of illumination has been estimated by Weston's technique and a more workable set of recommendations have been compiled. In the case of the surround field a similar investigation has been carried out by Moon and Spencer (4), who base their criterion for the quality of lighting on two concepts:—

(a) The adaptation Helios, which is the brightness to which the eyes are adapted when looking at the visual task and which is, in most practical cases, the brightness of the central field.
(b) The Delos, the relation between the visual acuity attainable with a uniform surround and that obtained with a background with an adaptation Helios or brightness, H_B.

In order not to reduce the Delos, the distribution of brightness in the surround

field must be such that, when the observer turns his eyes to any point, his adaptation level is sensibly unaltered. In practice the range suggested for Delos is between 1 and ½. This concept of Delos is important since it deals with the fundamental influence which effects visual performance, and thus frees us from the empirical requirement of a uniform field which is, of course, only a special case of a set of visual conditions yielding a high value of Delos.

In order to summarise in simple terms the conditions desirable for good seeing, the following criteria are suggested:—

(a) Details should be as large as practicable.
(b) Critical contrasts should be as high as possible without causing glare —say 50 or 100 to 1.
(c) The central field brightness should be of the order of 1,000 equivalent foot candles.
(d) The immediate surround field should be comparable in brightness with the central field, and, with the more remote surroundings, should be so coloured as to yield variety without distraction.
(e) The eyes of the operator should either be relaxed or accommodated well within the comfort range of the individual.

It is the duty of the illuminating engineer to interpret such a set of ideals into a practical lighting installation.

General and Local Lighting

A clearly defined policy is essential if industrial lighting is to lead to good seeing conditions. It would appear most satisfactory for the general shop lighting installation to be engineered as part of the structure of the building. No detailed attention should be given to the processes to be carried out in the shop. At the same time the lighting should be so planned that the layout of

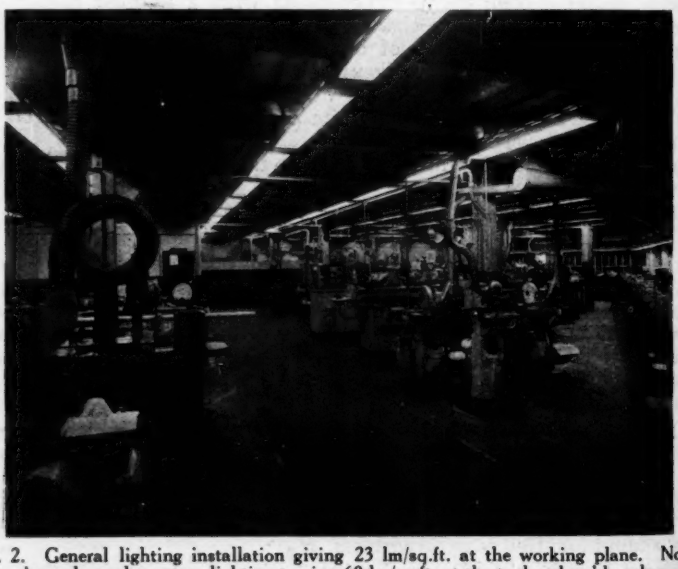


Fig. 2. General lighting installation giving 23 lm/sq.ft. at the working plane. Notice planned supplementary lighting to give 60 lm/sq.ft. at the tool-makers' benches.

the shop is in no way influenced by lighting requirements. The level of illumination provided in a shop will, of course, depend upon the class of work being carried out. Such an installation must, of course, be the responsibility of the Works' Engineer, in respect of planning, installation and maintenance.

For all general purposes an installation of this type should be adequate, and local lighting should always be the exception rather than the rule (see Fig. 2). There are many cases where either the nature of the work or the type of machine renders it necessary to supplement the shop lighting installation. In the case of a machine tool so designed that the work cannot be seen, it is clearly the responsibility of the machine tool designer to ensure that adequate supplementary lighting is built into the machine (see Fig. 3). The responsibility for installing local lighting and maintaining it must, of course, rest with

Fig. 3. Special purpose machine tool with built-in lighting. Flue of a very light finish is an integral part of the design of the tool.

the Works' Engineer, but since he may not be familiar with the details of all the processes in the shops, it is unreasonable to put upon him the onus for deciding when local lighting is necessary.

A further factor against the complete independence of the general and local lighting is the fact that the surround field brightness must, as has been shown, be related to the central field brightness. Not only must the general and local lighting for any particular job be planned together, but, if the best results are to be attained, the finish of all the interior surfaces of the shop, which make up the field of view, must be chosen with regard to the effect on the field of view of the operator. To provide good seeing conditions it is not only necessary to control the illumination on the job and its surroundings, but also the very nature of those surroundings. If the illuminating engineer is

to ensure success for his lighting scheme, he must control the paint on the ceiling and walls, also the finish and even the texture of the surface of the machine tools, and in extreme cases the work itself. This last may seem such an exaggerated view of the functions of the illuminating engineer that an example might be apposite. The use of coloured cards marked with light pencil is not uncommon in mechanised accounting systems, and equally prevalent is trouble due to eye strain, in spite of a good lighting installation. In this case it is clear that only white cards with all differentiating colours as borders should be allowed, and every effort should be made to ensure the use of soft instead of hard pencils.

The interdependence of lighting and decorating has been tacitly admitted for a long time in the "Room index" method of illumination calculation. Such a relation is, however, passive and a more active approach has become possible with the readiness of industry to accept new ideas on colour and decoration

Colour Harmony and Decoration

The subject of colour in industry falls essentially into two main divisions: (a) decorative colour, and (b) functional colour. In this paper the main concern is in the psychological effects resulting from the planned use of colour in decoration. However, the use of colour coding in industry has grown sufficiently important for the American Standards Association to recommend a series of signal colours for use in the factory and the B.S.I. has proposed a series of standard coding colours for services, etc. These two applications of functional colour should be applied in a slightly different manner, the former, being addressed to all workers, should be prominent; on the other hand, only the Works' Engineer's staff are concerned whether a particular pipe carries water or compressed air, and so the coding should be discreet. In either case the functional colour should be subservient to the decoration and must therefore be used sparingly. In fact its very success depends upon the work-people not becoming over-familiar with a riot of contrasting and conflicting colours.

The American recommendations are of general interest and are given in the following table:—

Table 1

A.S.A. Recommendations for Functional Colour

Colour	Function	Note
Red	Fire Equipment	——
Green	Safety Equipment	Conflicts with Red Cross for First Aid
Yellow	High Visibility	Attracts attention to Obstacles
White	Traffic Control	Gangway Lines
Orange	Danger Signal	Shown when a machine guard is not in position
Blue	Precaution	Control Switches, etc.

The use of red for fire equipment is already common practice, but there is an increasing tendency to use red for purposes where orange is proposed by the A.S.A. In the circumstances it would appear best to limit the use of red to fire appliances and use orange as a definite indication of other forms of danger. The method of use is important, for example there is a growing habit of painting machine guards a distinctive colour, which serves no useful pur-

pose. The use of an orange panel arranged to be exposed when the guard is open is a more satisfactory method of applying functional colour to this problem.

Again the use of white traffice lines is already common, although the metal stud may prove more serviceable. Yellow, particularly yellow and black bands, might be very valuable in certain circumstances when there is an awkward hazard. The value of the "Safety Green" and "Precaution Blue" would not at first sight seem to be very large. The Red Cross would seem to be the one permissible exception to the red for fire rule.

Although the selection of a colour for a functional purpose should be based on a knowledge of the psychological effects of colour, for example the conspicuity of orange and bright yellow, the subject is mainly an arbitrary one, and once the code has been agreed upon its value will depend upon the strictness with which it is followed. The decorative use of colour must, however, be treated in a different manner. The very root of the subject is its complete dependence on the psychological effects of light, shade and colour. Until recently all the knowledge and experience of the effects of colour and decoration on the human being have been largely empirical and quite uncoordinated. Such a state of affairs was inevitable when there was no scientific means of specifying colour or relating one colour with another, and also when the range of colours which were available for study was very restricted.

Colour Measurement and Harmony

In these circumstances the study of colour harmonies was the personal hobby of the artist, and although some few, even as early as Leonardo da Vinci, attempted to make some general statement, it was not until the colour systems of Ostwald and Munsell became available that any kind of objective treatment was possible. In recent times the Munsell colour solid has been related to the scientific method of colour specification, agreed internationally by the C.I.E.(5), and the results of Parry Moon's work (6) on the science of colour harmony can be expressed in terms either of the Munsell system or of his own more generalised colour space (7).

Parry Moon's work was carried out under strictly defined conditions which consisted in examining colour relations under a constant illumination and under a constant adaptation. The colour pattern occupied only part of the whole field of view, which was so controlled that the eyes were adapted to a neutral colour of Munsell Value 5 (19.3% reflectivity).

The following aspects of the problem of the aesthetic effects of colour have been studied:—

(a) The conditions for pleasing and displeasing relations between two colours.
(b) The relationship of a group of colours to give a harmony.
(c) The influence of area on colour relationships.
(d) The psychological effect of a colour harmony.
(e) Numerical assessment of the aesthetic worth of a colour harmony.

Such a study is clearly of immense value as a background to the study of decoration in a scientific manner. It must, however, be understood that, so far, the work applies only to the special case when the observer is adapted to a constant stimulus and a completely general approach to the subject has not as yet been worked out. Bearing this limitation in mind the study of colour harmonies can be used to indicate the lines on which work on industrial decoration should be carried out.

The Munsell Colour Solid

If the relationship between two colours is to be stated in an objective manner, which at the same time has a real meaning, some means of measuring and specifying colour must be used. For this purpose the Munsell system has two great advantages, namely:—

(a) It is simple and orderly.

(b) A Munsell colour step in any direction corresponds to an approximately equal change in sensation.

Other systems exist and many have a greater range of colours, but the lack of order and an exact correlation with the C.I.E. (1931) system renders them less valuable than the Munsell system. The Munsell colours are arranged on what may be thought of as a colour tree. The greys or neutral tints form the trunk, which is divided into ten equal steps between black and white, "Value" 0 and "Value" 10 respectively. The colours of the same "hue" are arranged on radial planes projecting from the central trunk, and the distance away from the trunk serves to indicate the "Chroma" or depth of the colour. The steps of Value or brightness, Hue and Chroma, are chosen so that they represent an approximately equal change in colour sensation, a point of very great importance in the use of the system for the study of colour harmony. The relationship is not exact, but it is sufficiently nearly so for the system to be used without any fear of gross errors arising.

Fig. 4 shows diagrammatically the arrangement of the colours in the Munsell system, from which it is evident that colour specification is very simple. The greys are designated N.2 or N.6 according to their values, whilst the chromatic colours can be expressed as R.6/4 for a red of value 6 and chroma 4.

Colour Harmonies

In the study of the relationship between two colours the following possibilities are found:—

(a) Identity
(b) First ambiguity
(c) Similarity
(d) Second ambiguity
(e) Contrast
(f) Glare (limited to value).

It is found that when the relationship is definite the effect is on the whole pleasing, but when the relationship is doubtful, as when two colours are so nearly the same that one is not sure if they are intended to be the same, then the effect is displeasing. In addition, of course, an excessive difference in Value is unpleasant, as it produces glare.

In Fig. 5 the regions corresponding to the five principal relations between the colour are shown for two cases:—

(a) A plane of constant Value and for colours of any Chroma

(b) A plane of constant Hue for colours varying in both Value and Chroma.

In the second case one of the two colours is supposed to be at the point 0.0 and the other may be anywhere in the pattern. Since all Munsell steps correspond to nearly the same sensation interval, Fig. 5 (b) can be imagined to be anywhere in the colour solid.

Harmonies of a Number of Colours

When more than two colours are to form a harmony, it is found that their points in the Munsell colour solid should form some regular geometrical figure.

For example, a pleasing harmony of three colours of the same Value would form a triangle, four colours a square, and so on. Such geometrical figures are, of course, not limited to the simple case of colours of constant Value, but may equally well lie in a plane of constant Hue or even an oblique plane through the colour solid.

Area Balance

It is well known that when one selects a sample of wall-paper the small cutting produces a completely different effect from the large expanse on the wall. The effect on a dark colour is apparently to increase in darkness as the area is increased, and similarly a light colour increases in lightness. These effects have been known and used by artists for centuries, but such effects can only be described with any degree of exactness in terms of some measurement.

It will be remembered that the colour harmony experiments were carried out with the eye adapted to a neutral tint of Value 5, and in these circumstances it was found that if two coloured cards of the same size were to have equal importance the colours must lie at the same distance from the point N.5 in the colour solid. Supposing, however, the two colours were at different distances from the adapting colour, then the ratio of their areas must be

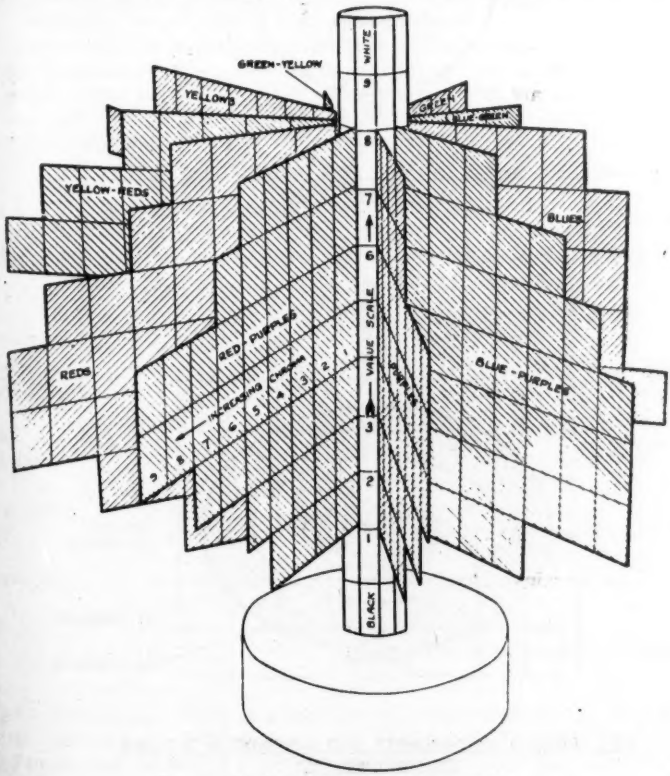
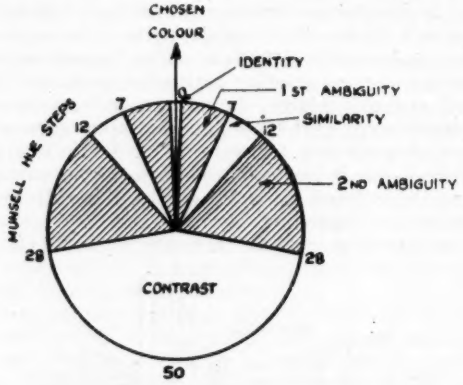


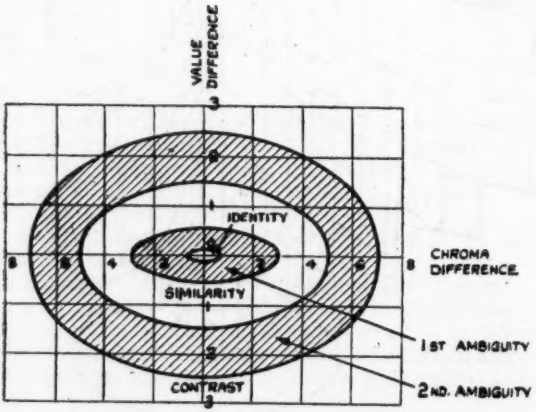
Fig. 4. The Munsell Colour Tree or Solid.

inversely as their distances from N.5. More exactly it is found that the moment of one colour about the point N.5 must be either equal to or be some multiple of that of the other colour.

These simple rules for the relation between two or more colours to give a harmonious combination and for controlling the areas of each component of a pattern are in no sense new. They have, in fact, been used either consciously or unconsciously for ages. Every woman knows that a light blue



(a) REGIONS OF SIMILARITY AND CONTRAST IN A PLANE OF CONSTANT "VALUE."



(b) REGIONS OF SIMILARITY AND CONTRAST IN A PLANE OF CONSTANT "HUE"

Fig. 5. Showing the relations between colours in the terms of steps in the Munsell Colour Solid.

scarf contrasts pleasingly with flaxen hair, and the severe black dress may be made far more attractive by a suitably chosen white collar—of much smaller area. The real importance of the statement of the laws of colour harmony lies in the fact that it is quite general and is no longer limited to the number of pigments which the artist happens to have available, or the range of dyes supplied to the dress designer. Within the present limitation of the eye being adapted to a neutral background of Munsell Value 5, all colour harmonies can be examined and accurately specified without the use of sample pigments.

This means of selecting and preparing colour harmonies does not in any way detract from or replace the creative imagination of the artist, but on the other hand it can enable him to create new effects by allowing him to specify new colours or combinations of colours without seeing them.

The Psychological Effects of a Colour Scheme

The rules of colour harmony state in simple geometrical terms what colours or groups of colours may be used together and in what quantities, but give no indication of the effect the pattern will have on the beholder nor how it will compare with any other pattern obeying the same rules. It is found that the reaction of an observer to a particular colour harmony depends on two factors,

(a) The average brightness or value of the whole pattern,

(b) The mean colour, which would be produced by mixing all the colours composing the pattern in proportion to their areas.

These two factors are, of course, interdependent in their action, the significance of the mean colour being negligible when the value of the pattern is low, but increasing and becoming dominant for a high value. Table 2 attempts to indicate the psychological effect to be expected from any pattern.

Table 2

Psychological Effect of Colours

Hue	Value	Chroma	Psychological Effect
Red		> 5	Very stimulating, very warm
Red-yellow		> 5	Stimulating, warm
Yellow		> 5	Slightly stimulating, slightly warm
Yellow-green		> 5	Slightly restful, neutral temperature effect
Green		> 5	Restful, slightly cool
Green-blue		> 5	Very restful, very cool
Blue		> 5	Non-stimulating, cool
Blue-purple		> 5	Non-stimulating, cold
Purple		> 5	Slightly stimulating, neutral temperature effect
Red-purple		5	Stimulating, slightly warm
Any	> 6.5	Any	Cheerful
Any	< 3.5	Any	Gloomy
Any	Any	< 5	Non-stimulating, neutral temperature effect

From the above table it is evident that if the mean value of a pattern is below 3.5 (8.8 per cent. reflectivity) it will always appear gloomy to an observer adapted to a mean value of 5 (19.3 per cent. reflectivity), but a pattern of mean value above 6.5 (35.2 per cent. reflectivity) will appear cheerful. Further it is

only for patterns having a value greater than 6.5 that the effects of the mean hue and chroma become significant. Of these the patterns of low chroma (i.e., less than chroma 5) have no specific effect, but the high chroma patterns have definite psychological effects depending on the dominant hue. These results are shown more graphically by means of Fig. 6 which represents a plane of constant hue in the Munsell colour solid, and can considered as typical of all hue planes.

Aesthetic Measure Applied to Colour Harmony

Having indicated the rules relating colours in a harmonious pattern and shown how to choose a group of colours to produce a specific effect, there remains

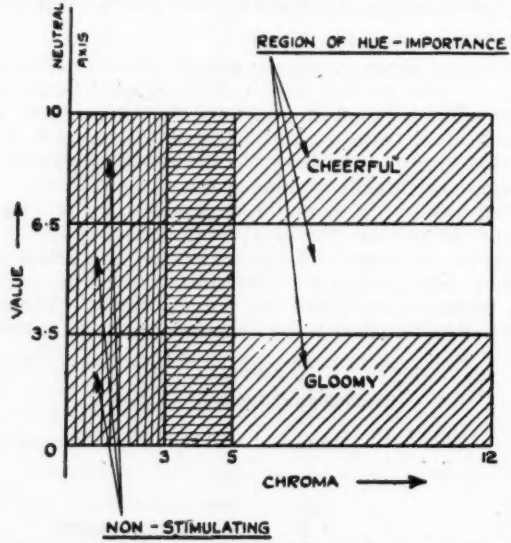


Fig. 6. Showing the regions of specific psychological effect in a plane of constant hue in the Munsell Colour Solid.

only the problem of how to evaluate a pattern in relation to other patterns, in fact to answer the question, how pleasant is the result. As with other aspects of colour harmony the idea underlying the system of aesthetic measure is by no means new. The ancient Greek view was that beauty consisted of "unity in variety" and it was left to Birkhoff (8) to attempt a general statement in quantitative terms. He suggested that the aesthetic merit, M, of an artistic creation could be expressed by the simple equation

$$M = O/C$$

where O represents the number of elements of order and C the number of elements of complexity. This was intended as a completely general idea and should be applicable to all forms of aesthetic appreciation. Birkhoff actually applied the equation to ornaments, vases, music and poetry and other workers have also been able to determine the appropriate mode of calculating the factors O and C.

Extending the methods of Birkhoff, the same fundamental equation can be applied to harmonies of colour. As a result of experiment the expressions de-

termining the values of O and C were deduced. The number of elements of order were found to require a rather complex treatment, which analysed the aesthetic merit of every possible relationship between two colours. These experimentally determined O values are given in Table 3. Calculation of the factor C proved to be less complex and it was found that the number of elements of complexity in a pattern could be expressed as:—

C = Number of colours
+ Number of pairs of colours with a hue difference
+ Number of pairs of colours with a value difference
+ Number of pairs of colours with a chroma difference.

Table 3

Aesthetic Factors

Number of elements of order associated with each colour relationship.

	Identity	First Ambiguity	Similarity	Second Ambiguity	Contrast	Glare
Hue	1.5	0	1.1	0.65	1.7	0
Value	—1.3	—1.0	0.7	—0.20	3.7	—2.0
Chroma	0.8	0	0.1	0	0.4	0
Grey	1.0	0	0	0	0	0

(Area balance—added 1.0 for equality of movements and 0.5 or 0.25 for ratios of 2 or 3.)

It is evident that, for the limited conditions in which the above experiments were carried out, the calculation of a quantitative value of M, the aesthetic merit, is quite straightforward. Before such a method of aesthetic measure can be applied accurately to a decoration scheme it is necessary to place it on a more general basis. For instance, the effect of adaptation to a level comparable with the mean value of the colour scheme itself must be considered. Such a change in the condition may be expected to alter the M value of a pattern in detail only, and not to affect the lessons to be learnt from the data given in Table 3.

Application to Industrial Decoration

An industrial decoration scheme may be looked upon as a pattern to be seen by an observer who is adapted to approximately the mean colour of the scheme. In the choice of such a decoration scheme care should be taken to choose

(a) a pleasing colour harmony;
(b) the mean value to give a cheerful atmosphere;
(c) the mean colour to be stimulating or restful as required;
(d) the whole to have as high an aesthetic merit as practicable.

In planning such an industrial scheme the rules of colour harmony are of great assistance, and an understanding of the basis of aesthetic merit also contributes largely to a successful effect.

The importance of using finishes having a high reflection factor to give a high mean value has already been pointed out and is desirable for two reasons, namely

(a) because of the beneficial psychological effect;
(b) because it enables efficient use to be made of the light given by the shop installation.

A wise use of the psychological effects of the mean colour of the decoration

scheme is potentially a great benefit for industry. Many processes inevitably lead to unpleasant conditions and might be made far more comfortable for the operators by suitable choice of the decoration. Probably the greatest field for the application of these effects will turn out to be in those industries where the work is repetitive and soon leads to boredom; in such circumstances a stimulating colour scheme might prove a great asset. In this connection it is particularly important to realise that the scheme must be planned for the operator who lives with it, and not to appeal to the factory manager who passes through it.

In deriving a quantitative measure of aesthetic merit it was shown that the elements exhibiting order was meritorious, but that the complexities of the pattern were disadvantageous. The industrial scene is generally very intricate, and so the first duty of the decorator must be to try to simplify an amazingly complicated scene, and then attempt to introduce order. The complexities of the situation will therefore demand the use of the simplest possible schemes. In composing a scheme care must be taken to apply the very important lessons to be learnt from Table 3. The most pleasing relation between two colours is clearly a contrast in value, which will give a very high contribution to the elements of order in any pattern, as exemplified again by the white collar on a black dress. At the same time it should be noticed that glare, which is an excessive value contrast, is the worst relation. It is in the handling of high and low brightnesses in the field of view that the greatest practical help can be expected from the application of Moon and Spencer's concept of Delos. Colour harmonies composed of colours of the same hue are also pleasing, but contrasts in hue may also be used to good effect.

A colour scheme of constant value would be most unpleasant and would be extremely boring. This is indicated by the low aesthetic factor for identity and the first ambiguity for value.

Recommendations for Industrial Decoration

The foregoing account of the theory of colour harmony can be summarised to give a set of recommendations for the practise of industrial decoration. However, before laying down such rules specifically, it is worth while considering the influence of personal taste on the appreciation of any particular scheme. If a person has an antipathy to a particular colour, it is certain that he or she will not appreciate to the full any scheme, however high its theoretical aesthetic merit, in which that colour plays an important part. This does not mean that the person may not understand that the pattern is in good taste, but, while understanding, he will nevertheless not feel comfortable in surroundings using such a scheme.

This influence of personal taste does not vitiate the whole system of the quantitative assessment of aesthetic merit, but it does render exact measurements impracticable, as is of course usual in most subjective assessments. On the positive side the effect of personal taste on any scheme may be very important, as it enables the character of the industrial organisation to be expressed in the taste shown by the management. Further it must be realised the scientific approach to the subject of industrial decoration cannot create a single new scheme, it can only help to stimulate appreciation and understanding. This is a point which both artists and scientists would do well to consider.

In view of the importance of allowing individual preferences to dominate

the choice of even an industrial decoration scheme, it must be appreciated that the following recommendations are guides only:—

(a) The ceiling, whether of the north light or horizontal type, should generally be painted white and have an eggshell finish. This choice is dictated by the necessity for
  (i) reducing to a minimum the glare from the lighting installation which should blend with the ceiling;
  (ii) making the best use of the light flux given by the installation.

(b) The walls and machine tools, which compose the principal elements of the colour pattern, should be in colours of high value and, whilst presenting variety, should not include contrasts in value. The average reflectivity should exceed 50 per cent. Except where the layout of the area makes it desirable, the use of the dado is not recommended, though for small areas a dado of a contrasting hue (but of high value) may be used to effect.

(c) Advantage should be taken of the aesthetic merit of the value contrast by picking out the skirting on the walls and machines and also makers' nameplates, etc.

(d) The floor can usefully contribute to the general effect, especially in the case of new buildings. Again a high reflectivity is desirable, but a mottled finish may lend interest.

Practical Application

Since these general recommendations are at variance with usual industrial practice, except in the case of the most progressive companies, it would seem advisable to quote the decoration now being used by the company with which the author is associated. The use of light finishes was introduced experimentally into the tool room in 1943. From the very beginning it was realised that the whole shop had to be re-decorated if worthwhile results were to be attained, because

(a) partial treatment would not yield any significant effect;

(b) unless the effect was immediately valuable there would be difficulty in keeping the walls and machine tools clean.

In point of fact a dark dado has been used in most of the shops treated, but from the very beginning cleaning of the machine tools has presented little or no difficulty. In the one section where a light wall finish is used down to the skirting the resulting appearance is far superior to that of the shops with the dark dado, Fig. 7. The colours used in these two practical cases are listed in the following table:—

Table 4

Decoration Schemes at Present Used in the Lucas Works

Location	Precision Shops		Trades Instruction School
Ceiling	White	75 per cent. reflectivity	White
Walls	Duck Egg Tint	60 per cent. reflectivity	Duck Egg Tint
Dado	Holly Green	10 per cent. reflectivity	——
Skirtings	Holly Green	——	Holly Green
Machine Tools	Portland Stone	55 per cent. reflectivity	Portland Stone

Obviously the most important single factor in the above, as in almost any industrial decoration scheme, is the machine tool. This is evident from Fig. 8, showing that from the workers' point of view, in a large shop, the machine tools

Fig. 7. General view of Lucas T.I.D. School

are by far the most significant part of the decoration scheme. They must get covered with swarf and oil, so at first sight it would seem unreasonable to expect

(a) to keep them clean if finished in a light colour;

(b) to maintain the light finish unblemished even if cleaned regularly.

Both these fears proved groundless. The machines were kept clean just because the dirt showed. Generally an oily machine means a faulty machine. The light finish shows up the oil and enables it to be serviced immediately. Again the lasting power of a good quality brushing machinery paint proved in nearly all cases to be excellent. In fact, after over three years, some of the original machines have received little more than occasional retouching, though it must be admitted that repainting is now necessary. Wet grinding machines proved the most difficult, and the only practical solutions to the problem of the deleterious effects of the grinding coolants seem feasible:—

(a) The use of one of the newer synthetic enamels which are quite unaffected by the most penetrating of coolants;

(b) The use of a low temperature stoving enamel.

(c) The use of a brushing cellulose enamel:

As might be expected, the experience of such a decoration scheme in a precision shop and in the hands of craftsmen cannot be taken as general for all other shops, where the tempo of work is quicker and only semi-skilled labour is employed. However, even in mass-production shops, the use of the same Portland Stone finish has proved practical on all special purpose machines and has now been standardised for all the machine tools designed and made in the organisation. In fact, the use of a light finish has now become an integral part of the lighting of some of these tools, Fig. 3.

New and Old Buildings

Much of the work that has been carried out on industrial decoration has been done in old buildings and often without stopping production in the shops.

Naturally this tends to limit the completeness with which the industrial scene can be controlled. In almost all cases it is difficult to do anything about the floor. Colouring a new concrete floor is practicable, and even an oily concrete floor may be cleaned and resurfaced. But an old and cracked floor or a wooden floor cannot be treated successfully. Again the services in most existing factories have been installed in a rather haphazard manner and reorganisation is usually an expensive and tedious task. The planning of the overhead services has become a matter of major importance in the re-lighting and re-decorating of many shops. Not only is the ceiling an essential part of the visual field, but the new fluorescent lighting fitting is very much larger than the old tungsten lamp fitting. Coupled with the rising level of illumination in a modern factory, this factor puts ceiling space at a premium.

Fig. 9 illustrates a test shop in a new building where every facility for control has been given, and the ceiling can be contrasted with the somewhat untidy appearance of some of the other illustrations.

For some time to come it must be expected that the majority of industrial decoration will have to be carried out in old or at any rate existing factories. Whilst this may not allow the decorator or lighting engineer to show his capabilities to the full, it is important to realise that there is an enormous amount of extremely valuable work to be carried out. Perhaps this point is exemplified most forcibly in the pioneer work reported by Brainerd (9, 10). The importance of treating each area as a whole is in the author's opinion one of the most valuable lessons to be learnt from Brainerd's straightforward experiment in transforming a small waiting room by re-decoration. The rewards for this work will not only be measured in terms of increased production but also in more fundamental human values. No matter how much people try

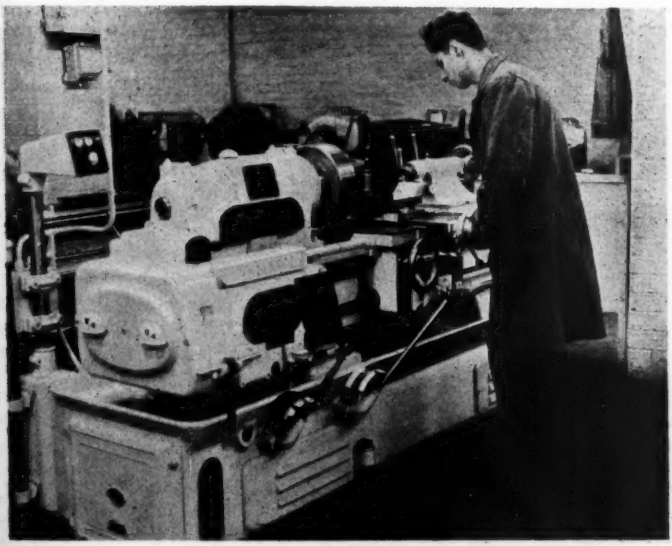


Fig. 8. Illustrating how the machine tool dominates the scene.

to pretend otherwise, they are influenced by their surroundings and, as the Chief Inspector of Factories says in the preface to the British Colour Council's booklet on Colour Schemes (10), "Factories should be places fit for people to live in."

This booklet gives a number of pleasing schemes suited for industrial use and is a really practical guide to procedure. It would appear, however, that many of the suggestions are made without due regard to the problem of long-term maintenance and to the necessary flexibility of industrial equipment. For example, if machine tools are moveable then it is essential that all the tools within a group, even in the whole organisation, should be the same or at least should be interchangeable. In the case of the light engineering industry when machine tools are small and layout must be flexible, it is best to paint all the tools in one colour. In other industries when the machines may stay installed in the same position for years, and particularly with large machines for, say, spinning, a different policy may be followed. In this case the machine is not just an element in a pattern and as such essentially simple. The machine itself may actually comprise most of the field of view and must be treated accordingly.

In the same way the recommendations in American trade literature show an immense amount of study has been put in to develop a number of good schemes. Too often, however, the schemes are over complicated or, more frequently, so many schemes are suggested for the same works that maintenance would require almost a library of paints! The problem of maintenance is one of the most important to be faced both in lighting and decoration, and it must in any case be relatively costly. It is, therefore, the duty of the artist and engineer so to plan their schemes that this cost is kept within bounds. It must also be realised that the repainting of a large factory, particularly a multi-story

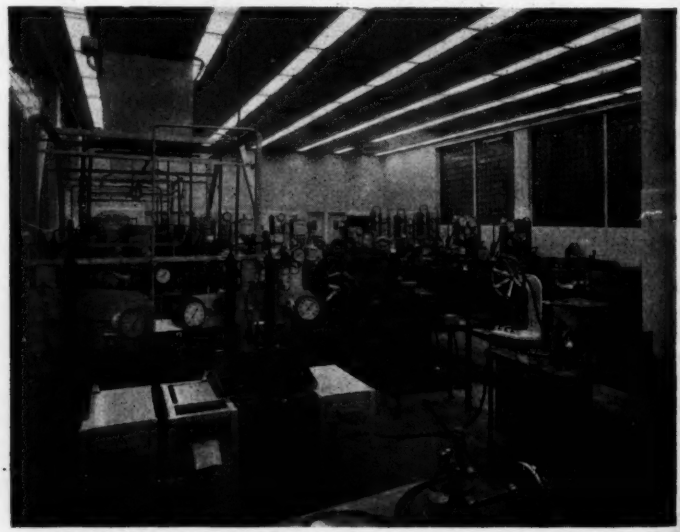


Fig. 9. Test house with flush lighting installation giving 26 lm/sq.ft.

building, takes a very considerable time. Complete repainting may take years in the ordinary maintenance routine. In these circumstances unless a fairly straightforward and simple policy is laid down and enforced, the whole factory can rapidly become a kind of cross section of different ideas and the whole history of its development will become painted on its walls.

Cost

As with lighting so with decoration, the cost of an installation in relation to its value in terms of increased production, or for that matter any production at all, is very difficult to assess. There is, however, one very important point to remember with regard to both lighting and decoration and that is that quality is much more important than quantity. The primary difference between a good and a bad lighting installation is not in the increase in foot candles in the former, but in the engineering of the installation, an item which, though still distressingly rare, is certainly not over costly. Clearly in the case of decoration, the walls and ceiling must be painted, so the choice of a pleasing colour scheme need at the most cost a consultant's fee. This is not, however, the complete picture. Machine tools are generally brought in finished and if a policy of refinishing machine tools is followed it must inevitably lead to an increased cost. In the future, however, there seems no reason why a machine tool should not be finished to the customers' requirements, particularly as this would enable a far more durable finish to be used than is usually possible to apply to the finished tool. In certain cases, such as capstans and most grinding machines, the use of vitreous enamel would be of immense value, and would not present a very serious problem to the manufacturers.

Conclusion

The potentialities of industrial decoration have not as yet been fully explored so any attempt to summarise the subject would be quite out of place. Direct experience of the effects of the use of planned decoration in industry is very limited, so it is necessary to draw on other fields as a guide. The wider studies of the psychological and aesthetic effects of colour can be used to indicate not only the course to adopt, but also to ensure the fundamental soundness of the ideas on which practice is based.

To be able to quote statistics to prove the value of good lighting and decoration in an unmistakeable manner would be pleasing, but such statistics are extremely difficult to obtain. Many are quoted, but careful examination always shows that other changes have also taken place. These changes weaken the value of the statistics so that generally it is preferable to refrain from quoting. For example, after the introduction of fluorescent lighting and finishing in light colours in one area, it was decided to note the change in accident rate over a period. Even such a simple record as this had to be abandoned because of other changes that took place at the same time. Admittedly wartime circumstances were exceptionally bad in this respect.

In spite of the lack of accurate data on which to assess the advantages of good seeing conditions, it is relatively easy to convince a management of their value as soon as the initial step has been taken. In one works where a programme had been tried experimentally in the plastic moulding shop, the superintendent reported that in a matter of weeks his labour turnover had fallen from being the highest in the works to one of the lowest. He now could choose

his operators whilst previously he was constantly in difficulties to maintain his labour force.

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Discussion

Mr. T. S. JONES said that whilst such a comprehensive presentation of this rather complicated subject left little scope for constructive criticism, he was somewhat concerned with certain inferences which might be drawn.

In the first place, it should be made clear that although fairly high surrounding brightnesses were usually desirable, visual acuity tended to decrease if the surround brightness exceeded the background brightness, so that the excessively light colouring of a large machine body might be detrimental if it was not practicable to ensure that the background of the work was kept at least as bright as the surround. It was not always easy to maintain the immediate background brightness at a reasonably high level.

The application of some of the theories, quoted in the paper, for conditions of maximum visual acuity applied to much normal work, but there were apparent exceptions. One that came to his mind was when a fine straight edge was used to check the flatness of a lapped machine surface and where detection of unevenness occurred by the passage of light, from a lamp or other artificial or natural light source, between the edge and the plane surface into the eye. Many workers who had been carrying on such work for 30 years and were well experienced in their work and, incidentally, in the application of light, held the view that a comparatively low surrounding brightness was more favourable than a comparatively high surrounding brightness, even when the actual background might be a well-illuminated diffused window. In general, a 30 per cent. factor was found to be comfortable in terms of equivalent brightness compared with the light source. In the same way a large amount of general lighting had been found to be detrimental because this caused reflection from near the side of the straight edge and this made it difficult to see whether light was leaking between the surface and the edge.

When considering decoration there was one point which the author might have brought out a little more clearly, and that concerned the effect of different light sources on colours. They were all well aware of differences between artificial light sources and daylight sources, but he felt that with the development of fluorescent lamps and fluorescent tubes it was necessary to be very careful. He had noticed—and would like some help from Dr. Nelson on this—that certain colours which were acceptable under daylight, particularly colours coming within the description of cream and beige, compared very badly under some forms of artificial lighting. Therefore, it was necessary to test any colours

which were to be used, under the actual light source. He was inclined to feel that a scientific approach to this subject was necessary. At the same time, perhaps there was just as much to be said for the artistic eye, so to speak. Experience from the artistic standpoint and from the interior decorator's standpoint might, he thought, be preferable to trying to work the job out with the Munsell tree on a sheet of paper.

Incidentally, he said, he had had experience of the maintenance of colour on machinery. In his firm's works there were machines which had been in use for 15 to 20 years painted in light colours, and it had been found quite possible to keep such machines in a normal machine shop in good condition. The operators tended to keep the machines in very much better condition than if the machines were painted in dark colours or left unpainted.

The author had evidently become an enthusiast after following the excellent policy of "trying it on the dog," and it was encouraging to know that in Dr. Nelson they had someone who had carried out much work of this nature under the difficulties of the war years, and he personally knew the large amount of travelling about the country and experimenting and of convincing the people concerned—which was the hardest of all tasks—that this work had entailed. Therefore, it was encouraging to find Dr. Nelson now coming forward full of enthusiasm. Nevertheless, he thought Dr. Nelson's enthusiasm took him rather far when, towards the end of his paper, he suggested the use of vitreous enamel for machine tool finishes and that it would not provide a big headache for the manufacturers. On the contrary, he himself was inclined to think that vitreous enamelling was probably unlikely to be applied to the large items because of the great difficulties due to the temperature required for fusion, the time cycle involved, the distortion likely to occur, the difficulty of machining to correct such distortion after vitreous enamel had been applied and the comparative fragility of vitreous enamel which would tend to show up in transport, in installation and in the normal life of the machine. On the other hand, some of the recent developments in the field of silicone paints, which fell between the normal plastic paints and vitreous enamel, might provide a very happy solution to such problems.

Mr. W. Allen said that in all the cases to which the author had referred he had been able to choose his colours, but there were a number of cases in which the choice of colours was more strictly controlled, due to the nature of the materials in the immediate environment. The first case of that kind that came to his notice was a wood-working shop where the wood sawdust was bright yellow. Apple green was considered for decorating this place, but such a colour combination was likely to be very unpleasant and it seemed to him that some colour in the blue range would be much more satisfactory. It was the case that most unfortunate results could be produced in the use of colour—especially strong colours—if one did not know what one was doing, and the choice of a wrong colour was much more serious than the choice of a neutral colour.

A second experience that had come to his notice during the past week was curiously enough again concerned with the use of apple green. This was a firm in the Midlands making use of a large number of sewing machines. The machines were coloured apple green but the workpeople objected and insisted on the machines being coloured black again. These people were working the machines on soft wood benches which became slightly oiled due to the passage of millions of yards of cloth over them and the wood had taken on a rich

sort of orange-brown colour, and to paint the machines a light green against that colour seemed quite wrong. The reaction of the workpeople was entirely reasonable.

Some time ago a case came to the notice of a colleague where again an apple green coloured sewing machine was used on a wood bench, and the workers in that case also asked that the machines should have the original black colour restored.

It seemed to him that with a good many natural materials like wood, the controlling colour could be reliably identified, but in the case of metals, such as bronze, the lustre of the surface made the problem much more awkward and he did not quite know what to do about it. He had seen bronze being used for gear cutting and felt that it upset the general colour scheme, although he had not a very clear idea of what he would have done to remedy the difficulty. Perhaps the author had had some experience of that problem.

One point that had struck him in going round various factories where colour had been introduced was that in many cases the use of the British Colour Code for services was most unhappy in its results. There might be hot water, steam under pressure, cold water and things like that in pipes, and the Code was then shown to be very inharmonious.

A practical point mentioned by the author was the question of light floors. Had the author explored the idea of using concrete paints which were now available? In general, they seemed surprisingly durable for protecting concrete from wear. A number of firms specialised in these paints.

There were two points about the tools themselves which interested him on the organisation side. One was that the tool maker might colour the machines before they were supplied, because a better job could be made then; but the specification for the colour treatment would have to be very carefully drawn, and the tool makers themselves would be well advised to go into the problems of using their tools so that they could secure the best results.

Then there was another point about sewing machines. The manufacturers gave them a highly polished finish which gave much specular reflection at the point of working. In a factory where sewing machines were being operated it was noticed that there was glare and specular reflection. There was also distraction due to the highly polished foot where the needle was going up and down very rapidly.

With regard to maintenance, he said he had noticed in some of the factories he had visited where apple green was used for the machines, that the maintenance appeared to be very bad, and in one factory he thought he had found the reason. It was that the moment any oil ran over the green surface the colour appeared very dirty, and the operators would not take good care of the machines. Apple green looked dirty as quickly as any colour he could imagine, probably because a warm coloured wash over a very cool colour always had a very poor appearance.

Mr. J. M. WALDRAM said that following on some of the author's experiments, his colleague, Mr. Stevens, and he had had some experimental decorating carried out in their own offices. Their experiments had emphasised the difficulty of choosing from small samples, colours which would be pleasing on large areas, and also in getting in practice colours correct to sample.

Early in the war there had been complaints that blast walls in certain shops obstructed the light. The cables were already loaded to capacity, so that it was impossible to give more light, but the application of whitewash to the walls cured the trouble. It was important, particularly to the buyer, to note

that more light meant a heavier running cost, whereas a coat of paint or whitewash was much less expensive, even though it had to be renewed from time to time.

We were beginning to realise that a lighting system did not stop with the fittings. It included the lamps, the lighting fittings, the decoration, and, finally, the eye; the problem was one and indivisible. He had been interested to note that in America, at the recent National Technical Conference of the Illuminating Engineering Society, several papers on these lines were presented, together with some excellent demonstrations of colour problems. He had also seen some colour photographs taken by a colleague—which, unfortunately, he had not been able to get to the meeting—of the Tennessee Valley Authority power stations in Southern America. The generators and turbines were painted in attractive colours in the same finish as that put on motor-cars, and they looked as if they had been polished every morning. Proper painting and decoration was a stimulus to good housekeeping in the factory.

Would the author give some further information on the higher brightness which he recommended? He believed mention had been made of a brightness of 1,000 equivalent ft.-candles, which meant an illumination of 5-10,000 lumens-sq. ft. The Americans were doing a lot of work on high levels, and they were recommending that when the illumination was high the brightness contrast on the field of view should be kept down. Some of the author's slides emphasised the dangers of going up to high contrast. However, the American figure of 3:1 brightness ratio seemed to him to be unnecessarily low; one had an impression of almost intolerable dullness, and wished for something black to look at for sheer relief! It was possible to go too far in restricting the brightness range.

Mr. Waldram asked whether the scientific methods were capable of specifying colours with a better discrimination and greater consistency than the skilled eye. He believed we had a long way to go with a scientific approach before it would be possible to do better than with the skilled eye of a trained man, which was a very delicate thing.

Mr. S. A. Wood thought it would be dangerous to argue either that there should be complete standardisation of colour schemes in a factory or that a different scheme for each department would be the right thing. An example he had in mind was that of a textile mill with a sizing room and a weaving shed adjoining. In the weaving shed the operator was completely surrounded with looms and could see very little of the walls, whereas in the sizing room the walls provided the immediate surroundings to the one large machine. These two instances must be regarded as separate problems. He felt that each department should be considered independently and the scheme for the whole factory correlated, using the minimum desirable number of colours.

Continuing, he said he realised that it is not easy to find a suitable word which meant treating in colour. In the case of industrial buildings "Decoration" did not fill the bill. Was there any relationship between the use of "Decoration" in the title and the author's recommendation that "the high aesthetic merit of contrast should be used to bring out the maker's name plates on machine tools"? Mr. Wood questioned the desirability of this and said that he had been embarrassed by painters "improving" schemes by picking out name plates and mouldings on machines with a contrasting colour. He felt that in building up a scheme contrasting colours should be used with discrimination to emphasise good features. Admittedly that was not easy in

existing factories, but it should be simplified as designs for factories and machines improved.

Saying that as an artist he found Professor Moon's papers difficult to follow, he asked whether Dr. Nelson would explain one point which was not clear. In the paper reference was made to judging the psychological effect from any pattern by "the mean colour, which would be produced by mixing all the colours composing the pattern in proportion to their areas." Was it possible to assess one's reactions to the scheme from the mean colour and to say "patterns of low chroma . . . have no specific effect"? Suppose a pattern was composed of a large area of pale blue-green and a small area of vivid red. Intermixed in proportion to their areas these colours would produce a colour of low chroma. But surely such a scheme would have some effect on the beholder.

Mr. J. WADDELL said the Factory Inspectorate was in favour of as much activity in regard to colour in industry as possible. The Department had been doing all it could to publicise this and encourage it, but he had seen a good many factories where a satisfactory colour scheme had not yet been considered. He agreed with the author on the primary importance of thinking of brightness first. The majority of factories at the present time were too dark, either under daylight or artificial light, and the first aim must be to get people thinking in terms of brightness and brightening up the machines. If people started off with that in mind, and if they followed the general principles of having white ceilings and using fairly light tones, such as light greens and blues, he did not think they could go very far wrong, and where mistakes were made, these could be remedied by trial and error.

He noticed in one of the early slides the machines were painted with a dark skirting and around that was a white outline. That was something he had not seen anywhere else and he thought it was a little undesirable. It did not look very well on the slide but it might appear better in actual practice.

He took it that the author was in favour of a light dado or none at all, although it had been said that a dark dado was better as it did not show up dirty marks and so on. However, his experience had been that there had not been serious trouble with light walls getting dirty but it depended very largely on the width of the gangways. If it were necessary for people to squeeze past, then the walls would, of course, get dirty.

With regard to housekeeping, undoubtedly bright surroundings increased the interest of the workers immensely and helped maintenance because oil leakage would show up quickly on a light coloured machine whereas on a dark machine it would not.

As regards machinery guards, he thought these should generally be the same colour as the machine. He had seen guards painted orange or red in sharp contrast with the remainder of the machine, but in his opinion that was wrong. The tendency now was to design the guard as part of the machine, and if it were painted it should not be treated in a manner that drew special attention to it; it was, however, advisable to paint bright red or orange the parts normally covered by the guard, so as to draw attention when it was missing. This applied to opaque guards.

Where the worker had to observe an operation or material through a guard there was a special problem on which he would like Dr. Nelson's opinion. A typical case was a printing machine where a fine colour-printed sheet had to be watched by the operator through a guard which had to be of grid construction because transparent plastics were not altogether satisfactory. He would

like to know what conditions would give the best vision. His own opinion was that there should be good local lighting within the guard and that the grid should be coloured matt black or perhaps a dark tone of the same colour as the machine.

With regard to picking out parts of a machine to give contrast and a bit of gaiety, he did not think picking out the name was a very good method because so much depended on where the maker put his name, and anyhow, who was interested in the name? It would be better to pick out a part of the machine that had special value, such as a control lever, or a stop button or speed control, or something which the operator might need to spot quickly. There might then be a utilitarian advantage from the colour contrast as well as an aesthetic advantage.

Mr. F. J. WILLIAMS expressed surprise that the decoration of canteens and recreational rooms attached to factories had not been dealt with. In these places he thought the artist might be allowed to run riot and there should not be monotony there after the workers had come from a well-decorated workshop where the interest must not be distracted from the machines. The decoration of the recreational rooms should be very different from that of the factory.

Referring to sewing machines, he said it was always a matter of surprise to him that they were finished in a manner which allowed a great deal of reflection. He often wondered whether it was necessary to finish these in a high-gloss paint, and if flat paints were not sufficiently durable, then a flat varnish or an egg-shell varnish could be added. From the painting contractors' point of view, they would prefer that machines were sent out by the makers in a primed and filled condition, leaving the final colour to be applied after the machines were installed.

Mr. S. D. LAY agreed wholeheartedly with the author that although the scientific approach to this subject was in the very early stages of development, it must—for this very reason—be fully discussed if progress were to be made.

With regard to the work of Moon, he had approached that with some misgiving and even perhaps a feeling of antagonism at the outset, but now felt that the theory of identities, ambiguities, similarities and contrasts was a very sane and practical approach, although later work might revise the values shown in Figs. 5 (a) and (b).

The use of observers to obtain or to confirm results was however fraught with danger. For instance, Maitland Graves also used observers and obtained different, and in some respects, contrary results.

As a further example, a questionnaire recently presented to 200 people to obtain their reactions to test colour schemes in a factory, produced still another set of answers, showing a significant preference for great variety and strong colour. These examples clearly indicated the necessity of the utmost care in setting questions, evaluating answers and applying conclusions if they were to be generally useful.

Commenting on what had been said of an alleged conflict between the artist and the scientist, he said that a short while ago he had started to paint in water colours, and, looking at the results, had come to the conclusion that the artist must be a very orderly person indeed.

He did not think that there was any fundamental conflict. Indeed, the

artist was perhaps an embryo scientist!—at least in the field of observation and orderly thinking.

As far as he was aware, there was in Britain no safety colour code similar to that of the A.S.A. reproduced in the paper. Could we hope for the publication of an authoritative recommended practice in the near future?

It would be a very good thing to have a uniform code throughout the country instead of the many more or less experimental arrangements at present in use.

Mr. J. B. HEALEY remarked that he did a decoration job recently, and was very anxious to show the client what a close study he had made of this subject and what a good decorator he was! He suggested a scheme of pale yellow and green together in blush colours, and presented it to his client as quite a new idea. His client approved the scheme, though he thought the whole business was a fallacy—but a very popular one.

Continuing, he said he thought the whole question of colour in factories and industry was a matter of psychology, understanding what was required in the factory, and appreciating the atmosphere and the job in progress, around which something could be built that would be pleasing.

Remarking that he did not know where to go for advice on lighting, he said there seemed to be an absolute paucity of pure lighting consultants, and the decorator had the feeling that he was being advised by somebody who sold lamps!

One point with regard to fluorescent lamps was a great bone of contention. He had been anxious to use these lamps in a place where there was a great deal of hand-sewing going on, but the customer said he had already tried them and found there was a great deal of vibration in the light, not normally noticeable, but which made it impossible to sew by hand. Was there an answer to that?

Finally, he asked if the author had any figures of increased output in factories where first-class lighting and colour schemes had been introduced? He had heard from an American paint manufacturer that there had been increased output in American factories, but would like to know whether there were any figures relating to British factories.

Replying to the discussion, Dr. NELSON expressed his appreciation of what Mr. T. S. Jones had said, and recalled that it was through Mr. Jones's kindness that he had first had the opportunity of seeing a factory so decorated as to be "a place fit to live in," to quote the words of the Chief Inspector of Factories.

He fully agreed with what Mr. Jones had said about the relation between the background brightness and that of the work. In the case of the straight edge, would it not be more correct to think of the object being seen as a bright line contrasted against a dark field? The surround brightness for such an object should be more nearly the weighted mean of the brightness of the bright line and its background rather than that of the line itself.

With regard to the influence of the source of light on the appearance of a coloured pigment, he agreed that the spectrum of the fluorescent lamp was such that certain pigments might give anomalous effects. Generally this was a subject for experimentation.

He would go further than Mr. Jones and say that because he was the

man who created, the artist was by far the most important person. At the same time it was that great artist Leonardo da Vinci who first wrote scientifically about art, as his "Treatise on Painting," for example, shows.

On the subject of vitreous enamel it seemed appropriate to point out that not long ago it was impossible to get a fluorescent fitting finished with vitreous enamel.

The author said he appreciated Mr. W. Allen's point concerning the influence of the work itself on the choice of colours, and admitted that he had not come across this effect in the light engineering industry. He also had had an unfortunate experience with apple green One of the subsidiaries of his firm had decided that they would not wait for recommendations from head office, but would install their own decoration and fluorescent lighting. All machine tools and walls of a shop were painted apple green, and some very poorly designed fluorescent fittings were badly installed. As a result of this it was decided that decoration was no good. A very wise decision for the particular scheme. In this case, of course, monotony was the main fault of the scheme, whilst in Mr. Allen's examples there was a marked "ambiguity" in relation between two of the main colours in the field of view. Possibly "distraction" might be a more suitable description of the effect in this case. In any case all examples served to illustrate the importance of adequate knowledge, or careful experimentation.

He liked Mr. Allen's little dig at the Colour Code, and he agreed that the results could be offensive in certain circumstances. The only man who wanted to see the pipe was the engineer who was doing something to it and perhaps it would be better just to paint the top of the pipe for identification purposes so that the people underneath did not see the colours.

As regards light floors, he said he had had a rather unfortunate experience in this connection in the use of paints and was not sure whether paint was the right answer. He had suggested the use of a coating of concrete with colour in it, although he rather suspected that concrete paints were of that nature. Nor was he quite sure that there should be a flat colour; perhaps a mottled colour might cover up the dirt which was inevitable on the floor. In the case of an entrance hall, for example, which thousands of people passed through each day, it was impossible to keep it absolutely clean and it would look less dirty if a fairly high brightness was used with a mottled finish.

As regard sending out machine tools already coloured, he thought it could be done in the case of small machines for which only a limited range of colours was required but in other cases where special treatment was required because of the work the machine had to do, then he thought it was better that the machine-tool maker should supply the machine with a coat of primer and let the user finish it as required.

(Mr. ALLEN said he had in mind a paint and not a coloured concrete for finish of floors.)

Continuing, Dr. Nelson, commenting on the remark by Mr. Waldram concerning good housekeeping, said that experience indicated that if work-people were provided with pleasant surroundings they would take considerable trouble to preserve them. In this connection he referred again to the experience of the bakelite moulding shop which he had mentioned in the paper in which the immediate reward for installing a decoration scheme was a sharp fall in the labour turnover.

In his opinion the very idea that there should be any conflict between the

scientist and the artist in this field of practical psychology appeared to indicate our appalling ignorance of the whole subject. He compared it with the articles in an old edition of the "Encyclopaedia Britannica" on the subject of diet. There were many and varied ideas put forward as to why green vegetables were an essential constituent of a balanced diet. This groping after the truth was almost childish when compared with our present-day knowledge of the function of vitamins. No doubt our discussions on colour harmony will sound equally ingenuous to the student of fifty years hence. But even then it is the artist who will remain the more important, because he will have the ability to create, and, also, will probably combine a full understanding of the scientific and technical sides of his subject—a habit of artists that it is not fashionable to recognise.

He agreed with Mr. Waldram on the dangers of using too high a brightness level without due care, and instanced an experimental installation which he had had put up to give 150 lumens per square foot. This was engineered in almost exactly the same way as the rest of the works which had an illumination level of 25 lumens per square foot, but whilst the latter was satisfactory, the experimental installation was by no means so.

Replying to Mr. Wood, he said he appreciated the importance of suiting the decoration scheme to the area and class of work carried out. He had, however, purposely over-stressed the need for simplicity, because, firstly, in the light engineering industry machines were often moved from shop to shop, and, secondly, to restrain the natural exuberance of those who might be tempted to overdo it!

Concerning the painting of nameplates Dr. Nelson said at least the machine-tool manufacturer would be interested in it, and he believed it could be done to give a beneficial effect. At the same time he agreed with the suppression of artistic licence, an example of which Mr. Waddell had spotted in the white outline round the base of the machine tools. He assured Mr. Waddell that it looked worse in actual practice.

He sympathised with Mr. Wood in his difficulty in following Professor Moon's work, and with regard to the question of colour mixing the frank answer was he did not know. However, he suspected that the true answer was that the effect of the thin red line, for instance, was almost negligible psychologically, in spite of the fact that it made an enormous difference aesthetically.

The author agreed with Mr. Waddell's comments about the dado and would like to add the point that, light or dark, the dado looked equally unsightly after a truck had been run into it.

On the subject of machine guards the object was to make them as inconspicuous as possible. So that in the instance quoted the guard should give the smallest possible contrast with the work, which should, if necessary, be lit from inside the guard. Where it was practicable the use of glass would seem to be desirable, though transparent plastics seemed to be finding a place, for example, in the construction of guards for special-purpose milling machines.

As Mr. Williams had so rightly pointed out, the canteens and recreation rooms needed an entirely different approach. As an example of how this problem might be tackled he mentioned one canteen he had visited which had been covered with murals executed by local talent and giving a most pleasing effect.

He agreed with Mr. Williams on the evil of using a high gloss paint and stated that a fellow lighting engineer had once tried to persuade typewriter manufacturers to use a matt finish so that the visual conditions for the typist

could be improved. He met with a complete refusal and it was only because of complaints of the workpeople building the typewriters that any change has been made at all.

In replying to Mr. Lay's comments on questionnaires he pointed out that the preparation of a questionnaire was in itself a technical problem which should be carried out by experts. It was of the utmost importance not only to refrain from asking leading questions, but also to refrain from demanding a high degree of creative imagination from people who had little or no imagination at all. In his opinion questions should be so framed that only a Yes or No was needed.

Dr. Nelson said that a straightforward answer to the fluorescent lamp problem mentioned by Mr. Healey was that there was a stroboscopic effect. Normally there were 100 flickers per second, but by linking the lamps up in a suitable way that rate could be increased to 300 per second and then the effect was not noticeable. He thought Mr. Healey had been rather hard on the consultant. At the present moment, nobody wanted to sell anything. Everything was over-sold so that it was possible to get honest advice. Nevertheless, Mr. Healey was right in deprecating the lack of completely independent consultants.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—" Trans. Illum. Eng. Soc. (London)."

REGISTER OF LIGHTING ENGINEERS

As announced at the Annual General Meeting of the Society held on May 13, 1947, the proposal to form a Register of Lighting Engineers was approved by a postal ballot of members.

The working details of the scheme have been prepared, and applications for inclusion on the Register are now invited, beginning from February 1, 1948. Forms of application may be obtained from the Secretary of the Society at 32, Victoria-street, London, S.W.1, or from the Hon. Secretaries of Centres and Groups.

The Register has been established to meet the need for some form of recognition for practising lighting engineers who satisfy the Council that they possess suitable qualifications. The regulations governing the inclusion of names of Corporate Members in the Register, and details of the qualifications required of applicants, are given in an appendix hereto.

Those admitted to the Register will be given a certificate to that effect, but the certificate remains the property of the Society and must on demand be returned to the Society. The certificate is issued by the authority of the Society only and does not convey any exclusive right to practise as a lighting engineer.

Corporate Members whose names are included in the Register will have the exclusive right to adopt the description "Registered Lighting Engineer (I.E.S.)." The Council are empowered to remove from the Register the names of all Registered Lighting Engineers who have ceased to be Corporate Members of the Society.

In the following Appendix the conditions to be complied with by applicants are set out. Attention is directed to para. 6 of the Regulations under which the conditions of para. 5 (ii) and 5 (iii) may be waived in the case of those Corporate Members who satisfy certain alternative conditions. As the scheme will come into operation on February 1, 1948, those wishing to take advantage of this paragraph must do so *before February* 1, 1950.

For the purpose of examining applications for inclusion on the register the Council has appointed a registration board, which in turn has invited a panel of assessors consisting of approximately forty Fellows of the Society, to advise them, as and when necessary, on the technical aspects of applications, and assist when necessary in the examination of a candidate's knowledge in specialist fields of lighting practice.

APPENDIX

Regulations governing the inclusion of the names of Corporate Members of the Society in the Register of Lighting Engineers.

INTRODUCTION

1. The name of a Corporate Member of the Society who is a practising Illuminating Engineer and who fulfils the conditions given in paragraph 5 below may, on approval by the Council, be included in the Register of Lighting Engineers (I.E.S.).
2. A Corporate Member whose name is included in the Register shall be exclusively entitled to adopt the description "Registered Lighting Engineer (I.E.S.)."
3. The Register shall in no way affect the rights of members as a whole nor shall registration be regarded as a condition either of Membership or of Fellowship.
4. Each Corporate Member whose name is approved for inclusion in the Register shall be required to pay an initial registration fee of one guinea.

QUALIFICATIONS

5. A Corporate Member applying to be placed on the Register must satisfy the following conditions:—

(i) have been a member in some class for not less than one year,

(ii) have passed the Intermediate examination in Illuminating Engineering of the City and Guilds of London Institute or have obtained an equivalent qualification approved by the Council,

(iii) have given satisfactory evidence of knowledge of ancillary subjects such as may be acquired in a Course at an Engineering, Architectural or other Technical Institution, (See paras 7 and 8 below.)

(iv) have successfully passed through a course of practical instruction approved by the Council of the Illuminating Engineering Society and involving service over a defined period in the departments of an organisation in the lighting industry,

or

prove to the satisfaction of the Council that he has been engaged in Illuminating Engineering practice for an approved period and has shown competency therein. (See para. 9 below.)

6. In the case of a Corporate Member who for ten years has had suitable practical experience in Gas Engineering, Electrical Engineering or other approved vocation, including, for not less than half this period, suitable experience in Illuminating Engineering, and who makes application within a period of not more than two years from the initiation of the scheme, the conditions laid down in para. 5 (ii) and (iii) above may be waived. Any period spent in the Services during the war shall be counted as half time in adjudicating experience. An applicant for this dispensation may, however, be required to undergo an oral and/or written test.

KNOWLEDGE OF ANCILLARY SUBJECTS

7. Ancillary subjects in which a certain standard is required are sub-divided into those that are compulsory and those in which some choice is permitted.

(*a*) COMPULSORY SUBJECTS:—

Mathematics to the standard of School Certificate with Credit.

Technical Drawing to the standard of a second year Evening Institute Course.*

Light and Heat to the standard of the School Certificate Examination in Physics.

*Such a course might be defined as follows:—

"Technical Drawing: Use and care of instruments, making of freehand sketches; geometrical projection; plans, elevation sections; printing, dimensioning and lettering generally; various views of fittings and small components, drawn from freehand sketches."

(*b*) SUBJECTS FROM WHICH A SELECTION MAY BE MADE:—

Electrical Engineering to the standard attained at the end of the second year of a three-years' day course at a Technical College or the Ordinary National Certificate in Electrical Engineering.

Gas Engineering to the standard of the examination in Gas Engineering (Supply) Ordinary Grade.

Architecture to the standard attained at the end of half of a four years' course or two-thirds of a three-years' course of training.

8. As an alternative to the requirements given in para. 7 above the following educational qualifications may be accepted as complying with para. 5 (iii) above:—

(i) The Joint Section "A" examination of the Institutions of Electrical Engineers and Civil Engineers,

or (ii) The Final Paper "B" of the City and Guilds examination in Illuminating Engineering.

PRACTICAL TRAINING

9. (i) An applicant shall be capable of applying accepted good lighting practice, including recognised Codes of Practice and regulations in regard to lighting.

(ii) An applicant shall be required to produce a certificate that he has been

engaged in the practice of Illuminating Engineering for not less than three years and that he is, if necessary, prepared to accept a practical test. He may produce a statement describing the work which he has done.

(iii) An applicant may be required to satisfy practical tests to reveal his knowledge of such of the following points as are relevant to the field of lighting practice in which he claims proficiency:—

(1) Light Sources and their characteristics.
(2) Polar Curves of Light Distribution, isocandle diagrams, etc.
(3) The selection of appropriate types of Fittings.
(4) The placing and siting of Lighting Units.
(5) Utilisation Factors.
(6) Illumination Values.
(7) Distribution Characteristics.
(8) Power required to furnish the requisite Illumination values.
(9) Economic Factors.
(10) The Provision of Facilities for Lighting and its control.
(11) Essential Accessories.
(12) Lighting in relation to Architecture and Decoration.
(13) Psychological Factors.
(14) Maintenance.
(15) Natural Lighting.

These tests may be applied in any one lighting field in which the applicant claims competence, but where knowledge is claimed in one field only, a higher standard will be expected than when the applicant is prepared to take the test in a number of alternative fields.

The Library

The following additions have been made to the I.E.S. Library:—

Section No.	Title.	Author.	Date.
1/62	Textbook of Illuminating Engineering	J. W. T. Walsh	1947
1/63	I.E.S. Lighting Handbook ...	I.E.S. (U.S.A.)	1947
6/5	The Technique of Stage Lighting	R. Gillespie Williams	1947
11/20	Luminous Tube Lighting (Second Edition)	H. A. Miller	1947
15/18	Researches of Normal and Defective Colour Vision ...	W. D. Wright	1946
23/28	British Standards Yearbook	... ...	—
23/29	Electricity in the Building Industry	F. C. Orchard	1946
23/30	A Chronological History of Electrical Development ...	National Electrical Man. Assn. (U.S.A.)	1946
23/31	Tests of Instruments for the Determination, Indication, or Recording of the Specific Gravities of Gases	U.S. Dept. of Commerce	1947
23/32	Highway Engineers' Reference Book	... ...	1947

The complete list of books in the Library was published in the TRANSACTIONS for September, 1946.

SESSIONAL MEETINGS IN LONDON

A sessional meeting was held at the Lighting Service Bureau, 2, Savoy-hill, London, W.C.2, at 6 p.m., on Tuesday, November 11, 1947, when the President (Dr. J. W. T. Walsh) was in the chair.

The minutes of the last meeting having been taken as read and confirmed, the President called upon Mr. J. S. Smyth, who had been unable to be present at the last meeting, to receive the Leon Gaster Memorial Premium for his paper entitled "The Brightness and Legibility at Night of Road Traffic Signs." The Secretary then announced particulars of forthcoming meetings.

The President then called upon Mr. F. Widnall to present his paper, entitled "The Design of Industrial Lighting Equipment." The paper dealt with the control of light output from industrial lighting fittings, and described tests that were carried out to ensure satisfactory performance.

After a vote of thanks, proposed by the President, had been carried, the discussion was opened by Mr. R. A. Joseph, who was followed by Mr. S. D. Lay, Mr. G. D. Mason, Dr. J. N. Aldington, Mr. J. B. Harris, Mr. C. R. Bicknell, and Mr. H. C. Weston. Mr. Widnall replied to the discussion, and the meeting was closed.

A further sessional meeting was held at the Lighting Service Bureau at 6 p.m. on Tuesday, December 9, 1947, when the chair was again taken by the President.

The minutes of the last meeting were taken as read and approved, and particulars of the next meeting were announced.

The President then called upon Dr. J. H. Nelson to present his paper, entitled "Decoration and Industrial Lighting." In opening his paper the author said that he proposed to deal with only some of the points given in the printed paper which had been circulated. He then showed and discussed a number of slides, some of which were in colour, illustrating the effects of decorative schemes in industrial premises. He also explained the Munsell colour system, and discussed the work on colour harmony which had been carried out in America.

After a vote of thanks proposed by the President had been carried, the discussion was opened by Mr. T. S. Jones, who was followed by Mr. W. Allen, Mr. J. M. Waldram, Mr. S. A. Wood, Mr. J. Waddell, Mr. F. J. Williams, Mr. S. D. Lay and Mr. J. B. Healey. The author replied to each speaker in turn.

Informal Meeting in London

The first informal meeting of the present session took place at the Lighting Service Bureau, 2, Savoy-hill, London, at 6 p.m., on Tuesday, November 25, when the chair was taken by Mr. J. S. Preston (Vice-President), and Prof. H. Hartridge gave a lecture on "The Polychromatic Theory of Human Vision."

In opening his lecture Prof. Hartridge outlined the accepted three-colour theory of vision, and mentioned other polychromatic theories that had been put forward in the past. He then described his own theory, explaining that it was of a purely experimental nature and therefore subject to considerable revision.

Following the lecture an interesting discussion was opened by Dr. E. N. Willmer, who was followed by Dr. M. H. Pirenne, Mr. P. J. Waldram, Mr. G. H. Giles and other speakers.

The meeting closed with a vote of thanks to Prof. Hartridge.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

SUSTAINING MEMBERS:—

Oldham Corporation Street Lighting Committee, Lighting Dept., Gas Street, Oldham, LANCS. ..... *Representative*: Mr. C. Worswick.

Walsall Corporation Electricity Supply Dept., Upper Bridge Street, Walsall, STAFFS. ..... *Representative*: Mr. Donald Holt.

CORPORATE MEMBERS:—

Armstrong, T. .....24, Prenton Dell Road, Prenton, CHES.
Ball, Miss G. F. .....47, Woodberry Grove, Manor House, N.4.
Belchambers, H. E. .....68, Ashlawn Road, Rugby, WARWICKS.
Benyon, R. W. J. .....84, New Street, Sutton, St. Helens, LANCS.
Bradley, R. .....Linton Court, 77, Holland Park, W.11.
Burton, R. .....37, Tenniscourt Drive, LEICESTER.
Callegari, A. S. .....21, Rippolson Road, Plumstead, S.E.18.
Camden, R. J. .....66, Sidwell Street, Exeter, DEVON.
Campion, J. H. .....Electric Light Fittings Association, 36/8, Kingsway, W.C.2.
Carruthers, G. .....169, Mayals Road, Blackpill, SWANSEA.
Clancy, W. J. .....50, Blackwood Street, GLASGOW, W.3.
Coates, T. .....51, Stonehill Avenue, Birstall, LEICESTER.
Connor, J. W. .....10, Alton Road, LIVERPOOL, 6.
Cooper, R. R. .....68, Schubert Road, East Putney, S.W.15.
Crawford, W. C. .....60, Kingsknowe Drive, EDINBURGH, 11.
Crawshaw, G. .....203, Bradway Road, Bradway, Nr. SHEFFIELD.
Cumming, W. K. .....18, Barclay Street, Paisley, RENFREWSHIRE.
Davies, C. W. ....."Rodene," Roborough, PLYMOUTH.
Dean, J. .....302, Herringthorpe Valley Road, ROTHERHAM.
Dickinson, S. .....17, Clevelands Grove, Morecambe, LANCS.
Green, C. F. .....Bognor and District Gas and Electricity Co., Argyle Road, Bognor Regis, SUSSEX.
Grubb, E. B. M. .....1, River Walk, Willow Bank, Uxbridge, MIDDX.
Hamill, J. M. .....35, Holme Avenue, Walkerville, NEWCASTLE-ON-TYNE.
Harris, C. B. .....High Street, Leek, STAFFS.
Hart, G. F. A. .....77, Lessingham Avenue, Upper Tooting, S.W.17.
Hibbitt, T. A. .....c/o Matthew Hall (Pty.), Ltd., 165a, Smit Street, Braam Fontein, Johannesburg, S. AFRICA.
Hook, S. R. .....7, Plevna Street, Cubitt Town, E.14.
Kingsley-Lark, G. T..."Ashfield," Strathmore Road, Rowlands Gill, Co. DURHAM.
Lawrence, R. W. .....85, Brisbane Road, Largs, AYRSHIRE.
Lee, D. N. .....58, Ealing Park Mansions, South Ealing Road, Ealing, W.5.
Leeming, E. L. .....Urmston U.D.C., Council Offices, Urmston, LANCS.
Lovett, J. D. .....30, Sunningdale Avenue, NEWCASTLE-ON-TYNE, 6.
MacGilvray, E. .....23, Longford Street, GLASGOW, E.1.
Maxwell N. .....14, Prince Road, Wallsend-on-Tyne, NORTHUMBERLAND.
Menzies, J. W. .....14, Sherfield Drive, Heaton, NEWCASTLE-ON-TYNE.
Montgomery, J. P. ..."The Abbotts," All Saints Road, CHELTENHAM.
Peat, G. J. .....38, Queensway, Waterloo, LIVERPOOL, 22.
Peyton, J. H. S. .....151, Wyld Way, Wembley, MIDDX.
Pope, R. J. .....17, Hartdale Road, Thornton, Nr. LIVERPOOL.
Reader, C. L. .....1, Sowden, Courtlands Lane, Lympstone, EXMOUTH.
Russell, J. F. .....10, Quarrybrae Avenue, Clarkston, RENFREWSHIRE.
Stewart, H. C. .....22, Fremantle Road, Taunton, SOMERSET.
Temple, A. R. .....c/o 11, Cemetery Road, Pudsey, LEEDS.
Thiel, F. A. .....3, Hillsborough Avenue, EXETER.
Thurner, W. .....Falk Stadelmann and Co., Ltd., 91, Farringdon Road, E.C.1.
Turner, E. .....29, Fairholt Road, Stoke Newington, N.16.
Waite, T. C. ....."Glenelg," Lena Avenue, Monkseaton, NORTHUMBERLAND.
Waller, J. D. .....48, Tosson Terrace, Heaton, NEWCASTLE-ON-TYNE.
Young, T. .....51, Camborne Grove, Gateshead, Co. DURHAM.

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